A review of the environmental implications of B2C e-commerce: a logistics perspective

Riccardo Mangiaracina, Gino Marchet, Sara Perotti and Angela Tumino
Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milano, Italy

Introduction and scope of the study

In spite of the bursting of the Dotcom bubble in 2000, over the last ten years business-to-consumer (B2C) e-commerce has grown in all of the main western markets. Although its penetration rate – online sales as a percentage of overall retail sales – is still below 15 percent in almost all of the leading countries (Mulpuru, 2013), its absolute value and average growth per year are increasing rapidly. The main contributors to this success include the wide range of products (Park *et al.*, 2012), very competitive prices (Bruce and Daly, 2010), the design of a high-quality customer experience (Brugnoli *et al.*, 2009), the choice of the best logistics strategy (Ghezzi *et al.*, 2012), and the premium service level (primarily in the management of returns) offered by online retailers (Wei and Zhou, 2011). In addition to these elements, which are mainly related to the retailer strategy, there are various systemic factors that are understood to drive the diffusion of e-commerce (Mangiaracina *et al.*, 2012). Examples of these include broadband availability, the definition of a legal framework for consumer protection, the

Received 24 June 2014
Revised 30 October 2014
19 January 2015
Accepted 26 February 2015

design of a "secure" value proposition (Rodiguez-Ardura *et al.*, 2008), trust in online systems (Mouratidis and Cofta, 2010), and the adoption of different payment systems (Mangiaracina and Perego, 2009).

In recent years, mainly due to increased environmental concerns (e.g. Golicic *et al.*, 2010; Mollenkopf *et al.*, 2010) and increased competitive pressure, sustainability issues have been attracting more attention from researchers and practitioners in the field of e-commerce. Different definitions of "sustainability" may be found, as highlighted by Carter and Rogers (2008). However, the most well known and most often quoted definition of sustainability is that of the Brundtland Commission (World Commission on Environment and Development, 1987, p. 8): "development that meets the needs of the present without compromising the ability of future generations to meet their needs." According to the Triple Bottom Line approach, sustainability has to take into account three components: natural environment, society, and economic performance. Considering people and the planet in addition to profit leads to a more sustainable outcome (Elkington, 1994; Colicchia *et al.*, 2013; Marchet *et al.*, 2014), and firm performance can be improved by balancing profits with social and environmental goals (Hart and Milstein, 2003; Porter and Kramer, 2006; Shao and Liu, 2012). Moreover, pressure from stakeholders may influence company awareness, the adoption of sustainability goals, and the implementation of a sustainable supply chain practice (Meixell and Luoma, 2015). Overall, sustainability is considered to be a key factor that can help firms improve both operations and strategic growth while at the same time gaining a sustained competitive advantage, and delivering sustainable values to the broader society (Hart and Milstein, 2003; Porter and Kramer, 2006).

Focussing on online retailing, wide-ranging environmental effects may derive from a number of factors, such as an increase information technology usage, the redesign or use of additional packaging (Williams and Tagami, 2003), and the physical distribution of items. Among these factors, logistics activities such as transportation and warehousing certainly represent a key component of the environmental sustainability of the entire supply chain (McKinnon *et al.*, 2012).

So far, the literature has widely attested the importance of sustainability issues for B2C e-commerce processes, and some attempts have been made to classify the research on this theme. Specifically, other literature reviews on the subject of B2C e-commerce have previously been conducted. For example, Ngai and Wat (2002) provided a review and a classification scheme for B2C e-commerce research. However, their analysis did not focus specifically on B2C e-commerce, but also took into account business-to-business (B2B) e-commerce, and the restricted timeframe covered (i.e. papers published between 1993 and 1999 in nine journals) means that the study is now out of date, and an analysis of more recent contributions is needed. Moreover, the sustainability perspective was not considered in their analysis. Another example is provided by Abukhader and Jönson (2003), who conducted a critical review of the extant literature on the environmental implications of both B2B and B2C e-commerce. The papers examined were published between 1991 and 2002, and journals on logistics/supply chain management, environmental science, and the field of e-commerce/e-business were taken into account. Interesting results were presented (e.g. the analysis of e-commerce effects in terms of transportation emissions and impacts on other processes, such as packaging and warehousing; the focus on different industries). Still, some drawbacks to that review were identified: first, the body of work examined is no longer current, and new key contributions have since been published; second, a structured discussion was not presented; third, some key themes, such as the issue of measuring the environmental impact of e-commerce or "green" initiatives, were not examined in detail or

were absent. Two other more recent reviews were found, namely those by Yi and Thomas (2007) and Velásquez *et al.* (2009). The work by Yi and Thomas (2007) considered various sources of information, including journal articles, peer-reviewed theses, project reports, conference and symposia proceedings, and web sites. The discussion centered on the type of source and the methodology adopted, but there was no detailed investigation of the key theme(s) of e-commerce sustainability. Velásquez *et al.* (2009), expanding upon the review by Abukhader and Jönson (2003), specifically focussed on e-commerce carbon footprinting, and investigated multiple industries. Nonetheless, as in Abukhader and Jönson (2003), some interesting perspectives were not investigated in detail, and several recent contributions were omitted. Overall, looking at previous contributions and reviews on B2C e-commerce, logistics operations have not yet been adequately assessed, despite their impact on the environmental sustainability of the entire supply chain, as commonly recognized in the literature (e.g. McKinnon, 2010; Venus, 2011). Moreover, due to the still limited diffusion of B2C e-commerce, logistics processes and solutions in the online scenario are still evolving and improving, and the measure of their environmental sustainability is a key performance indicator for their future development.

Coherently with the above premises, the present paper aims to overcome the limitations of the previous reviews and to categorize/discuss the literature in the arena of B2C e-commerce environmental sustainability from an up-to-date perspective, thus including recent contributions on this topic. The purpose is to focus on a specific aspect of sustainability, i.e. the environment, and to provide a review of the contributions on the topic of environmental implications of B2C e-commerce from a logistics perspective (i.e. in terms of logistics processes). The choice of focussing on such a specific – as well as promising – theme is motivated by the progressive diffusion of B2C e-commerce (Mulpuru, 2013), growing environmental concerns (Aronsson and Brodin, 2006), and the uncertain impact of B2C e-commerce logistics operations on the environmental sustainability of the business in the various industries (Edwards *et al.*, 2010). Specifically, the objective of this contribution is twofold: first, to classify the research on this topic as a guide for both practitioners and academics and, second, to identify gaps in the research in order to propose directions for future studies. The paper will provide both the scientific community and practitioners with a clear and holistic view of the environmental implications of B2C e-commerce, specifically related to logistics and transportation activities.

The remainder of the paper is organized as follows. The next section describes the methodology used in this study. The results of the review are then presented and discussed. To conclude, the limitations of the research are identified, and research gaps and potential directions for future research in this field are highlighted.

Methodology

Figure 1 presents the three-step methodology used in the present review. Phase 1 consisted of paper collection and selection, while Phase 2 involved a thorough analysis of the selected literature. Finally, research gaps and potential areas for further investigation were identified (Phase 3).

Phase 1: paper selection

In line with Srivastava (2007) the paper selection process included the following stages:

- Classification context: the classification context used to categorize the material was first identified (i.e. environmental implications of B2C e-commerce from a logistics perspective).

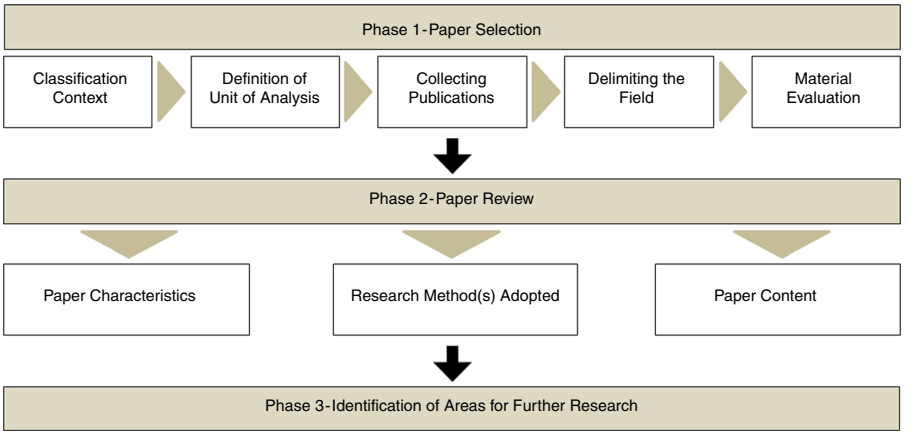

Figure 1.
Methodology

- Definition of the unit of analysis: the unit of analysis was defined as a single scientific paper published in an international peer-reviewed journal.
- Collecting publications: similarly to Perego *et al.* (2011), the starting point for the identification of relevant papers was a number of library databases (i.e. Scopus, Science Direct, ISI Web of Knowledge, and Google Scholar). The search was conducted using a number of keywords (i.e. "B2C," "e-commerce," "e-tailing," "online sales," "logistics," "sustainability," "green," "carbon footprint," "environmental implications," "environmental impact") and their combinations, used in both the abstract and the main body of the papers. To avoid the omission of other potentially important papers, as suggested by other authors (e.g. Marchet *et al.*, 2014), the majority of the cited contributions were also cross-referenced and, if necessary, included in the analysis. By applying this method, it was possible to assure adequate coverage of the extant body of research in this field.
- Delimiting the field: during the examination of the papers that were progressively found, some were recognized to be more significant than others for the purposes of the present study. As such, a sub-set of papers that deal with the environmental aspects of B2C e-commerce was finally selected, and 56 papers published from 2001 to 2014 were considered for in-depth investigation. The authors believe that the number of publications reviewed in this study is adequate given the scope of the analysis (i.e. focus on a restricted – although promising – subject), and this is consistent with previous contributions addressing specific research themes (e.g. Marchet *et al.*, 2014; Meixell and Norbis, 2008).
- Material evaluation: the literature was then analyzed and categorized. During this stage, a two-dimensional approach was taken to provide for a clear classification of the contributions examined and direct the discussion about the outcome of the review.

Phase 2: review method

Different methods used in previous literature-review papers (e.g. Carter *et al.*, 2007; Ghadge *et al.*, 2012; Meixell and Norbis, 2008; Natarajarathinam *et al.*, 2009; Perego *et al.*, 2011; Pettit and Beresford, 2009) were examined first. For the purposes of this review, the

selected contributions were classified based on: their main characteristics (i.e. year of publication, journal title, regions addressed), the research method(s) adopted, and their content. All of the papers were first summarized and then categorized in accordance with the review criteria, which was also helpful in identifying patterns that suggest interesting themes or possible gaps (Meixell and Norbis, 2008; Perego *et al.*, 2011).

Summary of review and discussion

Table I, based on Natarajarathinam *et al.* (2009), summarizes the key attributes of each paper, and the research method(s) adopted. Aligned with Perego *et al.* (2011), the papers are listed in chronological order to show the evolution of environmental sustainability issues related to B2C e-commerce over time.

Main characteristics of the papers examined

The 56 papers examined were published in 38 different scientific journals, with a mean value of 1.5 contributions per journal. The papers were published in different types of journals, i.e. environmental journals (43 percent), logistics and transportation journals (32 percent), information and communication technologies (ICT) or e-commerce journals (9 percent), or others (16 percent).

Focussing on the year of publication, the majority of the papers are relatively recent: more than 50 percent were published from 2007 on. A rising trend from 2001 to 2003 was observed, followed by a discontinuous curve. A further increase in the number of papers occurred from 2009 on, thus attesting to an increase in the amount of attention being paid by the research community to these issues. The reasons underlying this pattern may be explained as follows. On the one hand, this appears to be directly related to the growing interest that both companies and the stock market have shown toward B2C e-commerce: such interest grew until the bubble burst in 2000, it was then steady for a few years, and later rose again. The time required to conduct a research study, and for a paper to be written, reviewed, and accepted seems to explain the time lag between the bubble burst and the peak of contributions observed in 2002 and 2003, and growth observed after 2009. On the other hand, mounting environmental awareness in recent years has progressively led to an increase in the number of papers published about sustainability issues, as attested by Srivastava (2007).

Finally, looking at the regions addressed, it should be noted that the number of contributions in which the first author is from the USA is 15 (corresponding to 26.8 percent), followed by UK (seven, i.e. 12.5 percent). Other publications were written by researchers from China (four), Sweden (four), Germany (four), Finland (four), Japan (four), Finland (three), and the Netherlands (three). These results appear to be consistent with the spread of B2C e-commerce in the USA, UK, Germany, and Japan (i.e. the main markets) and also appear to reflect the increasing adoption of online shopping in China (i.e. the most promising emerging market).

Research method(s) used

Papers were classified and evaluated based on their research methodology. The categories used were based on a study by Meixell and Norbis (2008), who identified seven research methods, i.e. analytical/mathematical models, conceptual models or frameworks, case studies, interviews, surveys, simulation, and others.

As shown in Table I, many of the papers reviewed present conceptual models and frameworks (14) or are based on case studies (11) or simulation (11). In terms of the

Table I.
Summary of the reviewed papers

S.no.	Author (year)	Country[a]	Journal	Title	Research method(s)
1	Matthews *et al.* (2001)	USA	*Transportation Research Record: Journal of the Transportation Research Board*	Environmental and economic effects of e-commerce: a case study of book publishing and retail logistics	Analytical model
2	Punakivi and Saranen (2001)	Finland	*International Journal of Retail & Distribution Management*	Identifying the success factors in e-grocery home delivery	Simulation
3	Punakivi *et al.* (2001)	Finland	*International Journal of Physical Distribution & Logistics Management*	Solving the last mile issue: reception box or delivery box?	Simulation
4	Reijnders and Hoogeveen (2001)	The Netherlands	*Journal of Environmental Management*	Energy effects associated with e-commerce: a case study concerning online sales of personal computers in the Netherlands	Case study
5	Thornton and Ferrone (2001)	USA	*Environmental Quality Management*	The environment, e-commerce, and sustainability	Conceptual model
6	Fitcher (2002)	Germany	*Journal of Industrial Ecology*	E-commerce: sorting out the environmental consequences	Conceptual model
7	Hesse (2002)	Germany	*Resources, Conservation, and Recycling*	Shipping news: the implications of electronic commerce for logistics and freight transport	Conceptual model
8	Hossain (2002)	Malaysia	*Pakistan Journal of Information and Technology*	E-commerce and sustainability: concepts, issues ,and experiences	Conceptual model
9	Matthews *et al.* (2002)	USA	*Environmental Impact Assessment Review*	Energy implications of online book retailing in the United States and Japan	Simulation
10	Plepys (2002)	Sweden	*Environmental Impact Assessment Review*	The gray side of ICT	Conceptual model
11	Romm (2002)	USA	*Resources, Conservation, and Recycling*	The internet and the new energy economy	Conceptual model
12	Sui and Rejeski (2002)	USA	*Environmental Management*	Environmental impacts of the emerging digital economy: The e-for-environment e-commerce?	Conceptual model
13	Abukhader and Jönson (2003)	Sweden	*Management of Environmental Quality: An International Journal*	The environmental implications of electronic commerce. A critical review and framework for future investigation	Literature review

(*continued*)

S.no.	Author (year)	Country[a]	Journal	Title	Research method(s)
14	Lenz (2003)	Germany	*Transportation Research Record: Journal of the Transportation Research Board*	Will electronic commerce help to reduce traffic in agglomeration areas?	Conceptual model; survey
15	Matthews and Hendrickson (2003)	USA	*Journal of Industrial Ecology*	The economic and environmental implications of centralized-stock keeping	Case study
16	Siikavirta *et al.* (2003)	Finland	*Journal of Industrial Ecology*	Effects of e-commerce on greenhouse gas emission. A case study of grocery home delivery	Case study
17	Taniguchi and Kakimoto (2003)	Japan	*Journal of Eastern Asia Society for Transportation Studies*	Effects of e-commerce on urban distribution and the environment	Simulation
18	Williams and Tagami (2003)	Japan	*Journal of Industrial Ecology*	Energy use in sales and distribution via e-commerce and conventional retail: a case study of the Japanese book sector	Case study; analytical model
19	Abukhader and Jönson (2004)	Sweden	*International Journal of Technology Management*	E-commerce and the environment: a gateway to the renewal of greening supply chains	Conceptual model
20	Mokhtarian (2004)	USA	*Transportation*	A conceptual analysis of the transportation impacts of B2C e-commerce	Conceptual model
21	Cairns (2005)	UK	*Transport Review*	Delivering supermarket shopping: more or less traffic?	Case study; literature review
22	Gay *et al.* (2005)	USA	*Journal of Organizational Computing and Electronic Commerce*	Modeling paradigm for the environmental impacts of the digital economy	Simulation
23	Peng *et al.* (2005)	China	*Environmental Informatics Archives*	Optimism or pessimism: environmental impacts of the e-commerce	Conceptual model
24	Tehrani and Karbassi (2005)	Iran	*Iranian Journal of Environmental Health Science Engineering*	Application of e-commerce in local home shopping and its consequences on energy consumption and air pollution reduction	Survey
25	McLeod *et al.* (2006)	UK	*International Journal of Logistics Research and Applications: a Leading Journal of Supply Chain Management*	Transport impacts of local collection/delivery points	Case study

(*continued*)

Table I.

Table I.

S.no.	Author (year)	Country[a]	Journal	Title	Research method(s)
26	Farag *et al.* (2007)	The Netherlands	*Transportation Research Part A*	Shopping online and/or in-store? A structural equation model of the relationship between e-shopping and in-store shopping	Survey
27	Rotem-Mindali and Salomon (2007)	Israel	*Transportation Research Part A*	The impacts of e-retail on the choice of shopping trips and delivery: some preliminary findings	Conceptual model; survey
28	Sivaraman *et al.* (2007)	USA	*Journal of Industrial Ecology*	Comparative energy, environmental, and economic analysis of traditional and e-commerce DVD rental networks	Case study; analytical model
29	Yi and Thomas (2007)	UK	*Environmental International*	A review of research on the environment impact of e-business and ICT	Literature review
30	Abukhader and Jönson (2008)	United Arab Emirates	*Journal of Cleaner Production*	Eco-efficiency in the era of electronic commerce	Conceptual model
31	Primerano *et al.* (2008)	Canada	*Transportation*	Defining and understanding trip chaining behavior	Survey
32	Kim *et al.* (2009)	USA	*Environmental Science & Technology*	Designing and assessing a sustainable networked delivery (SND) system: hybrid business-to-consumer book delivery case study	Case study
33	Tehrani *et al.* (2009)	Iran	*Journal of Food, Agriculture & Environment*	Prediction of energy consumption and urban air pollution reduction in e-shopping adoption	Survey
34	Velásquez *et al.* (2009)	Canada	*Journal of Internet Banking and Commerce*	State-of-the-art in e-commerce carbon footprinting	Literature review
35	Weltevreden and Rotem-Mindali (2009)	The Netherlands	*Journal of Transport Geography*	Mobility effects of B2C and C2C e-commerce in the Netherlands: a quantitative assessment	Survey
36	Xu *et al.* (2009)	USA	*Environmental Science & Technology*	A dynamic agent-based analysis for the environmental impacts of conventional and novel book retailing	Simulation

(*continued*)

S.no.	Author (year)	Country[a]	Journal	Title	Research method(s)
37	Edwards *et al.* (2010)	UK	*International Journal of Physical Distribution & Logistics Management*	Comparative analysis of the carbon footprints of conventional and online retailing; a "last mile" perspective	Analytical model
38	Rizet *et al.* (2010)	France	*Procedia – Social and Behavioral Sciences*	GHG emissions of supply chains from different retail systems in Europe	Survey
39	Rotem-Mindali (2010)	Israel	*Transport Policy*	E-tail versus retail: the effects on shopping related travel empirical evidence from Israel	Survey
40	Weber *et al.* (2010)	USA	*Journal of Industrial Ecology*	The energy and climate change implications of different music delivery methods	Simulation
41	Yang and Zhang (2010)	China	*Chinese Business Review*	Empirical study on evaluation of regional agri-food logistics capability in e-commerce environment based on factor analysis – a case of study of Hebei Province	Case study
42	Zanni and Bristow (2010)	UK	*Energy Policy*	Emissions of CO_2 from road freight transport in London: trends and policies for long run reductions	Case study
43	Borggren *et al.* (2011)	Sweden	*The International Journal of Life Cycle Assessment*	Books from an environmental perspective – part 1: environmental impacts of paper books sold in traditional and internet bookshops	Analytical model
44	Edwards *et al.* (2011)	UK	*Supply Chain Management: An International Journal*	Comparative carbon auditing of conventional and online retail supply chains: a review of methodological issues	Conceptual model
45	Lim and Shiode (2011)	Korea	*International Journal of Physical Distribution & Logistics Management*	The impact of online shopping demand on physical distribution networks: a simulation approach	Simulation
46	Tiwari and Singh (2011)	India	*International Journal of Environmental Science and Development*	E-commerce: prospect or threat for environment	Survey
47	Wygonik and Goodchild (2011)	USA	*International Association of Traffic and Safety Sciences (IATTS) Research*	Evaluating CO_2 emissions, cost, and service quality trade-offs in an urban delivery system case study	Analytical model

(*continued*)

Table I.

Table I.

S.no.	Author (year)	Country[a]	Journal	Title	Research method(s)
48	Durand and Gonzalez-Feliu (2012)	France	*Procedia – Social and Behavioral Sciences*	Urban logistics and e-grocery: have proximity delivery services a positive impact on shopping trips?	Simulation
49	Teo *et al.* (2012a)	Japan	*Procedia – Social and Behavioral Sciences*	Evaluating city logistics measure in e-commerce with multi-agent systems	Simulation
50	Teo *et al.* (2012b)	Japan	*Transportation Research Record: Journal of the Transportation Research Board*	Evaluation of distance-based and cordon-based urban freight road pricing in e-commerce environment with multiagent model	Simulation
51	Wang and Yu (2012)	China	*Information Technology Journal*	E-commerce promote the development of low-carbon economy in Jilin province	Case study
52	Wiese *et al.* (2012)	Germany	*Transportation Research Part D*	Transport-related CO_2 effects of online and brick-and-mortar shopping. A comparison and sensitivity analysis of clothing retailing	Analytical model; case study
53	Fulton and Lee (2013)	USA	*Journal of Fashion Marketing and Management*	Assessing sustainable initiatives of apparel retailers on the internet	Survey
54	Zhang and Zhang (2013)	China	*Journal of Industrial Ecology*	A comparative study of environmental impacts of two delivery systems in the business-to-customer book retail sector	Analytical model
55	Carrillo *et al.* (2014)	USA	*European Journal of Operational Research*	Environmental implications for online retailing	Analytical model
56	Van Loon *et al.* (2014)	UK	*Journal of Cleaner Production*	A comparative analysis of carbon emissions from online retailing of fast moving consumer goods	Analytical model

Note: [a]First author's country is reported

other methodologies, a number of papers were found that are based on surveys (nine), and analytical models (eight). Four literature reviews were also examined, with Velásquez *et al.* (2009) being the most recent. No specific relationship was found between the type of research questions or themes addressed and the type of research method adopted within the papers. Nonetheless, some prevailing themes were identified for each of the research methods examined. For example, the empirical papers (i.e. based on either case studies or surveys) generally addressed the topic of the environmental implications of B2C e-commerce (e.g. Reijnders and Hoogeveen, 2001; Matthews and Hendrickson, 2003; Rotem-Mindali, 2010) or quantified the impacts in very specific contexts (e.g. Siikavirta *et al.*, 2003; Kim *et al.*, 2009; Tehrani *et al.*, 2009). The general environmental implications of B2C e-commerce were also analyzed qualitatively by means of conceptual papers (e.g. Fitcher, 2002; Sui and Rejeski, 2002; Mokhtarian, 2004; Peng *et al.*, 2005; Abukhader and Jönson, 2008), sometimes comparing conventional (i.e. in-store) and online shopping based on delivery execution, transportation impacts, and environmental externalities (e.g. Edwards *et al.*, 2011). Finally, quantitative models (i.e. analytical and simulation based) started to appear after 2001 for evaluating the environmental impacts of e-commerce (e.g. Matthews *et al.*, 2001; Taniguchi and Kakimoto, 2003). Their primary purpose is to support distribution network redesign after the implementation of the B2C e-commerce channel, or sometimes simply to measure the environmental effects of e-commerce processes. These models explore "green" implications (e.g. Durand and Gonzalez-Feliu, 2012; Zhang and Zhang, 2013), in some cases through a comparison between online and conventional channels, primarily in terms of CO_2 emissions (e.g. Edwards *et al.*, 2010; Weber *et al.*, 2010). Besides the evaluation of CO_2 emissions, some other measures have also been considered in the papers examined, e.g. NO_x, CO, PM_{10} (e.g. Kim *et al.*, 2009; Tehrani *et al.*, 2009), and, more recently, CO_2 equivalent emissions (e.g. Van Loon *et al.*, 2014).

Themes arising from the review

The papers were also analyzed based on content (i.e. issues tackled). In order to provide a clear classification of the articles examined and a focussed discussion of the outcome of this review, a two-dimensional approach was used to provide a comprehensive framework (Table II). The following two axes were considered when categorizing the papers: first, identification of the areas in e-commerce logistics operations that affect sustainability (both tactical/operational (e.g. transportation execution) and strategic (e.g. planning) areas were considered); second, measurement of the environmental effects of the areas identified, i.e. which performance indicators were evaluated.

Within this framework, an emphasis was placed on the contributions that compare e-commerce with conventional shopping from an environmental perspective. Finally, the papers that provide examples of "green" practices that e-commerce companies are adopting in the above-mentioned areas were also examined.

(i) Areas that affect the environmental impact of B2C e-commerce. Based on the papers examined (cf. Table II), the following main areas in e-commerce logistics operations that contribute to generating effects associated with sustainability were identified: transportation planning and management, warehousing, packaging, and distribution network design.

Transportation planning and management is the area most often tackled in the literature, if the number of papers that take transportation into account is considered as a proxy, i.e. 49 out of 56. Transportation decisions (i.e. in terms of both planning and management) have a significant impact on the environmental performance of an entire

Table II.
Classification of reviewed papers by areas that impact sustainability

Areas	Papers			
Transportation planning and management	Matthews *et al.* (2001)	Taniguchi and Kakimoto (2003)	Primerano *et al.* (2008)	Wygonik and Goodchild (2011)
	Punakivi and Saranen (2001)	Williams and Tagami (2003)	Kim *et al.* (2009)	Durand and Gonzalez-Feliù (2012)
	Reijnders and Hoogeveen (2001)	Abukhader and Jönson (2004)	Tehrani *et al.* (2009)	Teo *et al.* (2012a)
	Thornton and Ferrone (2001)	Mokhtarian (2004)	Weltevreden and Rotem-Mindali (2009)	Teo *et al.* (2012b)
	Fitcher (2002)	Cairns (2005)	Xu *et al.* (2009)	Wang and Yu (2012)
	Hesse (2002)	Gay *et al.* (2005)	Edwards *et al.* (2010)	Wiese *et al.* (2012)
	Hossain (2002)	Peng *et al.* (2005)	Rizet *et al.* (2010)	Fulton and Lee (2013)
	Plepys (2002)	Tehrani and Karbassi (2005)	Rotem-Mindali (2010)	Zhang and Zhang (2013)
	Romm (2002)	McLeod *et al.* (2006)	Weber *et al.* (2010)	Carrillo *et al.* (2014)
	Sui and Rejeski (2002)	Farag *et al.* (2007)	Zanni and Bristow (2010)	Van Loon *et al.* (2014)
	Abukhader and Jönson (2003)	Rotem-Mindali and Salomon (2007)	Borggren *et al.* (2011)	
	Lenz (2003)	Sivaraman *et al.* (2007)	Edwards *et al.* (2011)	
	Siikavirta *et al.* (2003)	Abukhader and Jönson (2008)	Tiwari and Singh (2011)	
Warehousing	Reijnders and Hoogeveen (2001)	Gay *et al.* (2005)	Borggren *et al.* (2011)	Carrillo *et al.* (2014)
	Abukhader and Jönson (2003)	Sivaraman *et al.* (2007)	Edwards *et al.* (2011)	Van Loon *et al.* (2014)
	Siikavirta *et al.* (2003)	Rizet *et al.* (2010)	Tiwari and Singh (2011)	
	Abukhader and Jönson (2004)	Weber *et al.* (2010)	Fulton and Lee (2013)	
Packaging	Matthews *et al.* (2001)	Williams and Tagami (2003)	Sivaraman *et al.* (2007)	Carrillo *et al.* (2014)
	Fitcher (2002)	Abukhader and Jönson (2004)	Weber *et al.* (2010)	Van Loon *et al.* (2014)
	Abukhader and Jönson (2003)	Gay *et al.* (2005)	Borggren *et al.* (2011)	
Distribution network design	Thornton and Ferrone (2001)	Sui and Rejeski (2002)	Kim *et al.* (2009)	Zhang and Zhang (2013)
	Hesse (2002)	Matthews and Hendrickson (2003)	Weltevreden and Rotem-Mindali (2009)	Van Loon *et al.* (2014)
	Romm (2002)	Taniguchi and Kakimoto (2003)	Lim and Shiode (2011)	

distribution process. Overall, the relevant literature does not suggest a general consensus regarding the environmental impact of transportation activities related to B2C e-commerce. On the one hand, some negative effects have been detected (e.g. Park and Regan, 2004; McLeod *et al.*, 2006), such as an increase in the number of inefficient deliveries (e.g. overnight deliveries by air and/or truck) and in shipping needs in general (e.g. home delivery of chilled products). On the other hand, under specific assumptions – e.g. high-population density, usage of low-carbon-emission vehicles – the environmental impacts can be positive, e.g. in terms of CO_2 emissions reduction (Hesse, 2002; Hossain, 2002; Siikavirta *et al.*, 2003; Rotem-Mindali and Salomon, 2007). However, some general observations may be made. First, the increasing growth of online purchasing and home delivery has contributed to the recent growth in van traffic, vehicles that consume more fuel and release more emissions per metric ton moved than larger vehicles (Allen and Browne, 2010). Second, unattended (i.e. failed) deliveries (McLeod *et al.*, 2006) and handling of consumer returns (Park and Regan, 2004) involve further travel and related greenhouse gas (GHG) emissions, the significance of which may vary depending on the industry sector. Third, consumers usually tend to purchase separate items from different web sites, each requiring independent deliveries (unlike the offline channel, where goods are bought on a single trip to the stores). The same occurs when purchasing multiple items (from one retailer) that are stored at different warehouses, thus involving separate deliveries. Finally, there are other critical environmental impacts associated with online purchasing, such as minimal travel savings by shopping online when goods would have been bought as part of a multi-activity trip if purchased via the offline channel (Primerano *et al.*, 2008).

Looking at "warehousing" (i.e. storage, picking, and material handling), although it is not normally considered a highly polluting process, it does affect energy usage (e.g. air conditioning and heating systems, if required). Warehousing was considered in 25 percent of the papers examined. In B2C e-commerce a competing effect may be observed. On the one hand, the tendency toward large warehouses leads to a reduction in total average inventory levels, and therefore reduced emissions and environmental impacts (Sui and Rejeski, 2002). On the other hand, both the large number of small deliveries and the handling of consumer returns are believed to lead to additional warehousing operations and increased complexity of picking and packaging activities, with consequent negative environmental implications (Matthews *et al.*, 2002).

Third, "packaging" can account for a significant portion of the GHG emissions due to e-commerce, especially when cardboard packaging is used. The importance of packaging is also borne out by the number of papers in this analysis that take this theme into account (i.e. 20 percent). B2C e-commerce is therefore generally held to have a negative environmental impact due to the individual packaging needed to ship a few products directly to the customers (e.g. Borggren *et al.*, 2011; Van Loon *et al.*, 2014) and to the additional protective packaging needed to deliver these items by express courier (Williams and Tagami, 2003). In this regard, the impact of shopping bags used by customers in conventional shopping is usually lower because of the limited amount of packaging used (Van Loon *et al.*, 2014). A notable exception occurs when physical products (e.g. music CDs) are replaced by digital downloads: in this event, B2C e-commerce has a positive impact on the environment.

Finally, implications from a "distribution network design" perspective should also be discussed, as 11 out of 56 papers (i.e. 20 percent of the papers examined) recognize the environmental impact of choices about the network structure. In fact, choices

related to the network structure are generally recognized to have a huge impact on the different aspects of sustainability (e.g. Winter and Knemeyer, 2013). Specifically, B2C e-commerce not only affects the planning and operations related to transportation, but also the structure of the entire supply chain, as globalization fostered by the internet makes it easier to purchase objects from very far away (Romm, 2002). Specifically, B2C e-commerce requirements differ from those of conventional channels, for at least to two reasons. First, the order profile – both in terms of size and frequency – is undoubtedly more challenging compared to the conventional channel, consisting of orders made up of a very limited number of pieces (i.e. only one in the majority of cases). Second, orders generally have to be delivered to the customer's house, with the additional problem of managing missed deliveries if the customer is not at home at the time of delivery. These differences imply new choices in terms of distribution network design. With regard to space needs, Romm (2002) estimated that B2C and B2B e-commerce together could reduce the need for one-and-a-half billion square feet of retail space in the USA – about 5 percent of the total – and up to one billion square feet of warehouses, with huge impacts in terms of lighting, heating, and cooling needs. Moreover, in e-commerce, large central warehouses seem generally to be preferred over local distribution centers, thus leading to reduced unit energy consumption and emissions (e.g. Matthews and Hendrickson, 2003). New delivery options related to B2C e-commerce have also been identified and recommended, as they are believed to be more sustainable and able to address the issue of missed deliveries. Pick-up points and parcel lockers are two such examples. Both are normally located at junctions or crossing points and allow consumers to collect products previously ordered online, with no need for express couriers to perform multiple deliveries, thus reducing total travel distances (e.g. Taniguchi and Kakimoto, 2003; Weltevreden and Rotem-Mindali, 2009).

(ii) Measurement of B2C e-commerce environmental effects. The papers were also analyzed and classified based on the type(s) of indicators used to assess the environmental implications of e-commerce (Table III). The following indicators were identified: "energy use," "gas emissions," "waste generated," and "traffic mileage." Although some of the analyses focussed on B2C e-commerce only, in most of the papers (more than 60 percent) a comparison between the online and conventional shopping from a "green" perspective was provided (italic text in Table III).

With respect to "energy use," Matthews *et al.* (2001) attempted to show the energy impacts of delivery systems in the USA and Japanese book industries. Delivery methods (such as traditional in-store shopping and home delivery) and distances to local bookstores were considered in their analysis. According to the authors, even with a return rate of 35 percent, B2C e-commerce logistics operations seemed to have lower environmental effects, especially if private car travel was used for shopping. There are case studies with similar purposes in the literature, which refer to different geographical areas: Japan (Williams and Tagami, 2003), USA (Kim *et al.*, 2009), and Sweden (Borggren *et al.*, 2011). The study performed by Kim *et al.* (2009) is particularly interesting since it introduced the concept of a sustainable networked delivery system.

In the articles that looked at "gas emissions," the authors focussed on conventional pollutants (e.g. CO, NO_x, PM_{10}), and/or GHG emissions (CO_2). The majority of the papers analyzed addressed only transportation activities, as transportation is generally believed to have the greatest impact on sustainability (Edwards *et al.*, 2010; Weber *et al.*, 2010). In this regard, last mile delivery has emerged as the most important of the transportation activities, since there is generally very little difference between the two

Energy use	Gas emissions: Conventional pollutants (e.g. CO, NO_2)	Gas emissions: Greenhouse gas emissions (e.g. CO_2)	Waste generated: Normal waste	Waste generated: Hazardous waste	Traffic mileage
Transportation planning and management					
Matthews et al. (2001); Reijnders and Hoogeveen (2001); Fitcher (2002); Hesse (2002); Matthews *et al.* (2002); Williams and Tagami (2003); Gay *et al.* (2005) ; Peng *et al.* (2005); *Sivaraman et al. (2007)*; *Kim et al. (2009)*; Tehrani *et al.* (2009); *Xu et al. (2009)*; *Rizet et al. (2010)*; *Weber et al. (2010)*; *Borggren et al. (2011)*; *Edwards et al. (2011)*	*Matthews et al. (2001)*; Hossain (2002); *Taniguchi and Kakimoto (2003)*; *Gay et al. (2005)*; Peng *et al.* (2005); *Tehrani and Karbassi (2005)*; *Sivaraman et al. (2007)*; *Kim et al.* (2009); Tehrani *et al.* (2009); Borggren *et al.* (2011); Teo *et al.* (2012a, b)	*Matthews et al. (2001)*; Fitcher (2002); Siikavirta *et al.* (2003); *Gay et al. (e)*; *Sivaraman et al. (2007)*; *Kim et al.* (2009); *Xu et al. (2009)*; *Edwards et al. (2010)*; *Rizet et al. (2010)*; *Weber et al. (2010)*; Zanni and Bristow (2010); *Borggren et al. (2011)*; *Edwards et al. (2011)*; Wygonik and Goodchild (2011); Wang and Yu (2012); *Wiese et al.* (2012); *Van Loon et al. (2014)*		*Matthews et al. (2001)*	Punakivi and Saranen (2001); Fitcher (2002); Romm (2002); Lenz (2003); *Siikavirta et al. (2003)*; *Cairns (2005)*; *McLeod et al. (2006)*; *Primerano et al. (2008)*; Tehrani *et al.* (2009); *Weltevreden and Rotem-Mindali (2009)*
Packaging					
Matthews et al. (2001); *Matthews et al. (2002)*; *Williams and Tagami (2003)*; Gay *et al.* (2005); *Sivaraman et al. (2007)* ; *Weber et al. (2010)*; Borggren *et al.* (2011); Zhang and Zhang (2013)	Matthews *et al.* (2001); Gay *et al.* (2005); Sivaraman *et al.* (2007); Borggren *et al.* (2011)	*Matthews et al. (2001)*; *Gay et al. (2005)*; Sivaraman et al. (2007); *Weber et al. (2010)*; *Borggren et al. (2011)*; Zhang and Zhang (2013); *Van Loon et al. (2014)*	Fitcher (2002); Hossain (2002); *Borggren et al. (2011)*	*Matthews et al. (2001)*	
Warehousing					
Reijnders and Hoogeveen (2001); *Gay et al. (2005)*; *Sivaraman et al. (2007)*; *Rizet et al. (2010)*; *Weber et al. (2010)*; *Borggren et al. (2011)*; *Edwards et al. (2011)*	*Gay et al. (2005)*; *Sivaraman et al. (2007)*; *Borggren et al. (2011)*	*Siikavirta et al. (2003)*; *Gay et al. (2005)*; *Sivaraman et al. (2007)*; *Rizet et al. (2010)*; *Weber et al. (2010)*; *Borggren et al. (2011)*; *Edwards et al. (2011)*; *Van Loon et al. (2014)*			
Distribution network design					
Romm (2002); Matthews and Hendrickson (2003); *Kim et al. (2009)*; Zhang and Zhang (2013)	Matthews and Hendrickson (2003); *Kim et al. (2009)*	Matthews and Hendrickson (2003); *Kim et al. (2009)*; Zhang and Zhang (2013); *Van Loon et al. (2014)*		Matthews and Hendrickson (2003)	

Notes: In italics text: papers providing a comparison between the online and conventional shopping from a "green" perspective

Table III. Classification of reviewed papers by areas (that generate effects in terms of sustainability) and by indicators (used to assess environmental implications of e-commerce)

alternatives (i.e. online vs conventional shopping) for most of the other transportation activities (Wiese *et al.*, 2012). Taniguchi and Kakimoto (2003) developed a vehicle routing and scheduling model to evaluate the effects of B2C e-commerce on urban freight transportation and on the environment in terms of pollutants (NO_x emissions). They highlighted the advantages of pick-up points compared to direct delivery when B2C e-commerce adoption is still low. More recently, Edwards *et al.* (2010) expanded the scope of the analysis by also introducing bus transportation as a means of reaching conventional stores, and focussing on GHG emissions. By introducing the bus transportation opportunity, neither home delivery nor conventional shopping proved to have an absolute CO_2 advantage, although in most cases B2C e-commerce home delivery operations generate less CO_2. Another assessment of CO_2 emissions related to e-commerce transportation was carried out by Durand and Gonzalez-Feliu (2012), who used simulation to compare two picking models used by online retailers, i.e. in-warehouse picking with home delivery vs in-store picking that combines both home delivery and pick-up in store. They observed that in-store picking appears to be least favorable in terms of environmental impact, mainly because the use of commercial vehicles for home delivery has not been optimized. With regard to the grocery industry, several authors investigated the impact of replacing private transportation with home delivery services on gas emissions. Siikavirta *et al.* (2003) estimated the GHG emission reduction related to both transportation and warehousing, and emphasized that results in Finland are highly dependent on the home delivery model adopted. More specifically, depending on the delivery model used (based on the time slots the customer can choose and the type of delivery, i.e. at home, in reception boxes, pick-up in store), the GHG emissions generated by grocery shopping can be reduced by 18-87 percent compared to the case in which household members go to the store themselves. Rizet *et al.* (2010) also focussed on the reduction of CO_2 emissions related to transportation and warehousing. Specifically, they collected data about consumer travel behavior in the UK, France, and Belgium through an online survey in order to obtain more reliable estimates of GHG emissions. In fact, the quantity of GHG directly emitted by the final consumer's shopping trip is generally an important part of the total supply chain transportation emissions. Last mile delivery also represents an important contributor to the total environmental impact in the book industry. Buying a paper book from an internet bookshop, having it delivered by regular mail at home or walking to pick it up, could be the environmentally preferable way to buy a paper book (Borggren *et al.*, 2011). In addition to last mile delivery, there is a strong relationship between CO_2 emissions and unsold items. In fact, they represent a serious problem in conventional trading, since they can generate considerable extra flows of products from the stores to the warehouses (with consequent extra-transportation activities). Depending on the specific industry, the proportion of unsold items can be over 35 percent of the items entering the stores. For instance, in the book and DVD industry CO_2 emissions from conventional shopping are higher than in the online case due in part to unsold items (Matthews *et al.*, 2001). Finally returns can have an appreciable impact on CO_2 emissions (Ghezzi *et al.*, 2012; Wang and Lalwani, 2007; Wiese *et al.*, 2012). According to Ghezzi *et al.* (2012) they can be up to 30 percent of overall online sales. In the case of returns, there is an impact due to extra flows of products from customers' homes to distribution warehouses, which can make conventional commerce more sustainable than e-commerce (Wiese *et al.*, 2012).

Just a few papers address issues related to "waste generation." Fitcher (2002) highlighted that one of the major concerns about e-commerce business models is the packaging materials used in logistics networks for product fulfillment and delivery. Matthews *et al.* (2001) focussed on the hazardous waste generated by trucking, air freight, packaging, fuel production, and book production. More recently, Borggren *et al.* (2011) observed that distribution of books to traditional bookshops requires less packaging than distribution via internet bookshops.

Finally, there are some interesting contributions related to "traffic mileage," in which the authors calculated the potential impacts of B2C e-commerce on personal and freight travel. Cairns (2005) estimated that vehicle travel in the UK can be reduced by 70 percent or more under the assumption of substituting car trips by van trips. When more complex shopper behaviors are considered (e.g. preference for buying fresh products at conventional stores) the benefits proved to be lower, but – according to empirical evidence – still existed. Weltevreden and Rotem-Mindali (2009) focussed on the Netherlands and identified a net mobility effect, where the reduction in personal travel due to e-shopping was not fully compensated by the increase in freight transportation. The authors highlighted that this mobility reduction can be attributed to B2C e-commerce only, as C2C e-commerce (i.e. a type of B2C e-commerce in which consumers directly interact with each other in order to buy, sell, or trade items online) led to an increase in both personal travel and freight transportation.

(iii) Green initiatives. Lastly, the papers were analyzed to identify potential examples of "green" practices adopted by e-commerce companies in the areas considered. The theme of "green" initiatives has received little attention, with just a few papers specifically devoted to that topic: only 15 percent of the papers tackled this issue, and case studies were the main methodology used. Some papers mentioned – mostly to a limited extent – a number of environmental sustainability initiatives adopted in the B2C e-commerce arena, specifically addressing transportation planning and management. In this area, the following practices have been observed:

- Use of alternative vehicles (González-Benito and González-Benito, 2006; Jumadi and Zailani, 2010; Lieb and Lieb, 2008): the use of electric or hybrid vehicles for home deliveries instead of conventional vans or trucks may contribute to a significant reduction in CO_2 emissions, together with energy savings. For example, Edwards *et al.* (2010) mentioned Sainsbury's, which planned to convert its online grocery delivery fleet to electric vans. Other relevant initiatives have been highlighted by Zhang and Zhang (2013), who focussed on the environmental impacts of B2C delivery in the retail book industry. They noted the widespread use of vehicles such as electric bicycles by transportation companies in China for delivering books from distribution points to final customers. One of the most recent examples of using alternative vehicles to deliver goods is a pilot project launched by Amazon based on drones. The company declared that by 2018 drones will be used in the USA to deliver products (weighting less than 2.3 kg) within 30 minutes of being ordered and within ten miles of the warehouse.

- Use of more recent/less polluting vehicles (Cairns, 2005; Lin and Ho, 2008; Lieb and Lieb, 2010), or use of alternative fuels such as biodiesel to power distribution trucks (Cairns, 2005; Fulton and Lee, 2013). As an example, Cairns (2005) highlights that for home deliveries the employment of new fuels, cleaner petrol or diesel, better filtration of emissions and quieter vehicles could reduce the negative effects of B2C e-commerce services.

Conclusions and directions for future research

Given the importance of logistics operations in B2C e-commerce supply chains and growing interest in both the academic and practitioners' communities about the related environmental effects, the aim of the study was to provide an up-to-date review of the literature on the topic of B2C e-commerce environmental sustainability from a logistics perspective. The analysis focussed on a set of 56 selected papers published from 2001 to 2014 in 38 peer-reviewed international journals. Previous reviews dealing with e-commerce sustainability were found in the extant literature, although they presented a number of limitations related either to the considered timeframe (i.e. lack of recent contributions) or to content/structure (e.g. lack of a thorough examination of the environmental implications of B2C e-commerce from a logistics perspective). This review was carried out to overcome the above-mentioned limitations, and was organized into three main sub-sections: discussion of the main characteristics (i.e. year of publication, journal title, regions addressed), research method(s), and content of each paper.

The papers identified were mainly published in environmental (43 percent) and logistics and transportation journals (32 percent). The articles are relatively recent (50 percent of the papers were published from 2007 onward) and it should be noted that, consistently with the development of e-commerce, a significant proportion (i.e. 40 percent) of first authors on these articles are from the USA or UK.

In terms of the methodologies used, many of the papers examined present conceptual models and frameworks (25 percent) or are based on case studies (20 percent). A number of the papers were based on surveys (20 percent), simulation (20 percent), and analytical models (15 percent).

With regard to content, several interesting themes were identified. Specifically, four main areas in B2C e-commerce logistics operations have been found to have an environmental impact, namely transportation planning and management, warehousing, packaging, and distribution network design. Four main types of indicators used to assess the environmental implications of e-commerce have been identified, namely energy use, gas emissions, waste generated, and traffic mileage.

More than 90 percent of the papers take into account the environmental impact of gas emissions or energy use generated by transportation planning and management activities (Table III). The other two important clusters revealed on Table III are those that comprise the papers that consider the impact on gas emissions or energy use determined by both packaging and warehousing (18 percent each). Papers that take into account the impact of traffic mileage are limited to the transportation planning and management area. Contributions that assess the impact of waste generated are very few in number and are mainly limited to the packaging area. Finally, only a few papers tackled the environmental impact of the distribution network design in terms of both energy use and gas emissions.

This paper has both academic and practical/managerial implications. From an academic viewpoint, this study contributes to knowledge in this arena by providing a structured classification of the existing body of research on the topic of B2C e-commerce environmental sustainability, specifically taking into account the logistics perspective. This viewpoint is particularly valuable, given the progressive growth of B2C e-commerce, along with related logistics activities, and growing environmental concerns (Aronsson and Brodin, 2006).

From a practical perspective, the present paper contributes to the understanding of B2C e-commerce sustainability from different viewpoints. It provides practitioners with a clear view of the key issues in terms of environmental sustainability of B2C

e-commerce processes, focussing on their logistics implications and it presents a full picture of all of the most important articles on this subject, including a classification that can help practitioners quickly find those papers that interest them. More specifically, the two axes considered in this review represent different sources of value to practitioners. First, classifying the papers by the logistics area that generates the environmental impact has helped identify which activities have the most significant environmental implications and, consequently, suggests a list of priorities for practitioners who want to improve their company's performance. Taking into account the implications related to distribution network design – seldom considered when tackling environmental sustainability – has also suggested some ways of enhancing one of the strategic areas that is most important for B2C e-commerce companies. Second, the classification by KPI provides practitioners with some existing indicators for measuring the environmental impact (e.g. in terms of gas emissions, energy use, waste generated, and traffic mileage). In addition, better knowledge about the KPIs may help the company develop better ways of communicating their environmental performance to customers (both acquired and potential) that can help improve the strategic growth of the company and implement more sustainable values with benefits for the entire society (Hart and Milstein, 2003; Porter and Kramer, 2006).

Furthermore, this paper clearly identifies the main environmental consequences related to the online channel as compared to the conventional one. It also highlights some green practices that have recently been implemented by companies, giving managers strong grounds for further investigation when making decisions about developing green projects. This is an important strategic issue for those involved in establishing or improving an e-commerce initiative. Finally, this literature review highlights an important aspect that practitioners must be cognizant of: environmental implications depend on the specific context within which a company operates (e.g. high-population density, usage of low-carbon-emission vehicles) and, in consequence, universal models do not exist. Practitioners should use this literature review as a guide to identify those cases that best fit their situation, but it is important that the models and assumptions then be tailored to reflect their specific needs. Our review, in which the first author of 40 percent of the papers is either English or American, provides practitioners with references from countries in which B2C e-commerce is the most widespread, including practical examples from 11 papers that present case studies.

Although a good picture of the extant literature has been formed, the literature review revealed that a number of key issues have still not been adequately addressed or have not been considered at all. This represents a limitation not only for academics, but more importantly for practitioners who are in need of clarity and a comprehensive coverage of all aspects of the subject matter.

First, the extant literature refers primarily to industries such as books and grocery, while sectors such as clothing (e.g. Wiese *et al.*, 2012) and consumer electronics (e.g. Gay *et al.*, 2005) have thus far been examined only in part or not at all. In the authors' opinion, this is a significant gap for two main reasons. Clothing and consumer electronics have experienced the greatest growth in sales over the last five years, as shown by reports by multinational research companies (e.g. Evans and Camus, 2010), and have become the most important industries in the B2C e-commerce scenario. They are also two of the most complex industries from both the logistics and environmental perspectives (e.g. proportion of returns, special requirements for products in the warehouse).

Second, despite increasing attention by both traditional retailers and online merchants to multichannel strategies (i.e. the integrated use of both the online and the offline

channels), the environmental implications and impacts of multichannel shopping experiences have not yet been investigated in depth.

Third, although the main impacts have been examined in terms of energy use and gas emissions, there continues to be a general lack of quantitative models for measuring the environmental impact of B2C e-commerce and dividing it among the supply chain players. In fact, the majority of the papers analyzed simply provide a qualitative assessment of the impact, which is very often simply a comparison between the two different ways (e.g. online vs offline) of conducting the same activities.

Fourth, tactical and/or strategic areas, such as transportation planning and distribution network design, have not been adequately addressed in the extant literature. The authors strongly believe that the environmental impact of these activities could be as much as an order of magnitude higher than that of the other areas, but the relationship between causes (i.e. activities) and effects (i.e. environmental impact) is in this case hard to identify and model.

Lastly, this study has one potential limitation that should be noted. Although efforts were made to be all-inclusive, as Perego *et al.* (2011) recognized in their review of ICT for logistics and transportation, some studies could have inadvertently been omitted from this review. Nonetheless, the authors are confident that the present review offers an accurate representation of the body of research on B2C e-commerce environmental sustainability from a logistics perspective published during the specified timeframe, and therefore the resulting assessments are considered to be reliable.

References

Abukhader, S.M. and Jönson, G. (2003), "The environmental implications of electronic commerce: a critical review and framework for future investigation", *Management of Environmental Quality: An International Journal*, Vol. 14 No. 4, pp. 460-476.

Abukhader, S.M. and Jönson, G. (2004), "E-commerce and the environment: a gateway to the renewal of greening supply chains", *International Journal of Technology Management*, Vol. 28 No. 2, pp. 274-288.

Abukhader, S.M. and Jönson, G. (2008), "Eco-efficiency in the era of electronic commerce – is there a need for adopting 'eco-effectiveness'?", *Journal of Cleaner Production*, Vol. 1 No. 7, pp. 801-808.

Allen, J. and Browne, M. (2010), "Vans and the economy", project report, Commission for Integrated Transport.

Aronsson, H. and Brodin, M.H. (2006), "The environmental impact of changing logistics structures", *International Journal of Logistics Management*, Vol. 17 No. 3, pp. 394-415.

Borggren, C., Moberg, A. and Finnvreden, G. (2011), "Books from an environmental perspective – part 1: environmental impacts of paper books sold in traditional and internet bookshops", *The International Journal of Life Cycle Assessment*, Vol. 11 No. 2, pp. 138-147.

Bruce, G.M. and Daly, L. (2010), "Innovative process in e-commerce fashion supply chains", in Edwin Cheng, T.C. and Tsan-Ming Choi (Eds), *Innovative Quick Response Programs in Logistics and Supply Chain Management*, Springer Berlin, Heidelberg, pp. 227-241.

Brugnoli, G., Mangiaracina, R. and Perego, A. (2009), "The ecommerce customer journey: a model to assess and compare the user experience of the ecommerce websites", *Journal of Internet Banking and Commerce*, Vol. 14 No. 3, pp. 1-11.

Cairns, S. (2005), "Delivering supermarket shopping: more or less traffic?", *Transport Reviews: A Transnational Transdisciplinary Journal*, Vol. 25 No. 1, pp. 51-84.

Carrillo, J.E., Vakharia, A.J. and Wang, R. (2014), "Environmental implications for online retailing", *European Journal of Operational Research*, Vol. 239 No.3, pp. 744-755.

Carter, C.R. and Rogers, D.S. (2008), "A framework of sustainable supply chain management: moving toward new theory", *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 5, pp. 360-387.

Carter, C.R., Kauffman, L. and Michel, A. (2007), "Behavioral supply management: a taxonomy of judgment and decision-making biases", *International Journal of Physical Distribution & Logistics Management*, Vol. 37 No. 8, pp. 631-669.

Colicchia, C., Marchet, G., Melacini, M. and Perotti, S. (2013), "Building environmental sustainability: empirical evidence from logistics service providers", *Journal of Cleaner Production*, Vol. 59, pp. 197-209.

Durand, B. and Gonzalez-Feliu, J.G. (2012), "Urban logistics and e-grocery: have proximity delivery services a positive impact on shopping trips?", *Procedia – Social and Behavioral Sciences*, Vol. 39, pp. 510-520.

Edwards, J.B., McKinnon, A.C. and Cullinane, S.L. (2010), "Comparative analysis of the carbon footprints of conventional and online retailing: a 'last mile' perspective", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 No. 1, pp. 103-123.

Edwards, J.B., McKinnon, A.C. and Cullinane, S.L. (2011), "Comparative carbon auditing of conventional and online retail supply chains: a review of methodological issues", *Supply Chain Management: An International Journal*, Vol. 16 No. 1, pp. 57-63.

Elkington, J. (1994), "Towards the sustainable corporation: win-win-win strategies for sustainable development", *California Management Review*, Vol. 36, pp. 90-100.

Evans, P.F. and Camus, L. (2010), "Western European Online Retail Forecast, 2009-2014", available at: www.forrester.com/Western+European+Online+Retail+Forecast+2009+To +2014/fulltext/-/E-RES56543 (accessed November 12, 2013).

Farag, S., Schwanen, T., Dijst, M. and Faber, J. (2007), "Shopping online and/or in-store? A structural equation model of the relationships between e-shopping and in-store shopping", *Transportation Research Part A: Policy and Practice*, Vol. 41 No. 2, pp. 125-141.

Fitcher, K. (2002), "E-commerce, sorting out the environmental consequences", *Journal of Industrial Ecology*, Vol. 6 No. 2, pp. 25-41.

Fulton, K. and Lee, S.E. (2013), "Assessing sustainable initiatives of apparel retailers on the internet", *Journal of Fashion Marketing and Management*, Vol. 17 No. 3, pp. 353-366.

Gay, R.H., Davis, R.A., Phillis, D.T. and Sui, D.Z. (2005), "Modeling paradigm for the environmental impacts of the digital economy", *Journal of Organizational Computing and Electronic Commerce*, Vol. 15 No. 1, pp. 61-82.

Ghadge, A., Dani, S. and Kalawsky, R. (2012), "Supply chain risk management: present and future scope", *International Journal of Logistics Management*, Vol. 23 No. 3, pp. 313-339.

Ghezzi, A., Mangiaracina, R. and Perego, A. (2012), "Shaping the e-commerce logistics strategy: a decision framework", *International Journal of Engineering Business Management*, Vol. 4 No. 13, pp. 1-13.

Golicic, S., Boerstler, C. and Ellram, L. (2010), "'Greening' transportation in the supply chain", *Sloan Management Review*, Vol. 5 No. 2, pp. 47-55.

González-Benito, J. and González-Benito, O. (2006), "The role of stakeholder pressure and managerial values in the implementation of environmental logistics practices", *International Journal of Production Research*, Vol. 44 No. 7, pp. 1353-1373.

Hart, S.L. and Milstein, M.B. (2003), "Creating sustainable value", *Academy of Management Perspectives*, Vol. 17 No. 2, pp. 56-67.

Hesse, D. (2002), "Shipping news: the implications of electronic commerce for logistics and freight transport", *Resources, Conservation and Recycling*, Vol. 36 No. 3, pp. 211-240.

Hossain, A. (2002), "E-commerce and sustainability: concepts, issues and experiences", *Pakistan Journal of Information and Technology*, Vol. 1 No. 2, pp. 188-192.

Jumadi, H. and Zailani, S. (2010), "Integrating green innovations in logistics services towards logistics service sustainability: a conceptual paper", *Environmental Research Journal*, Vol. 4 No. 4, pp. 261-271.

Kim, J., Xu, M., Kahhat, R., Allenby, B. and Williams, E. (2009), "Designing and assessing a sustainable networked delivery (SND) system: hybrid business-to-consumer book delivery case study", *Environmental Science & Technology*, Vol. 43 No. 1, pp. 181-187.

Lenz, B. (2003), "Will electronic commerce help to reduce traffic in agglomeration areas?", *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1858 No. 3, pp. 39-46.

Lieb, K.J. and Lieb, R.C. (2010), "Environmental sustainability in the third-party logistics (3PL) industry", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 No. 7, pp. 524-533.

Lieb, R.C. and Lieb, K.J. (2008), "The North American third-party logistics industry in 2008: the provider CEO perspective", *Transportation Journal*, Vol. 49 No. 2, pp. 1-25.

Lim, H. and Shiode, N. (2011), "The impact of online shopping demand on physical distribution networks: a simulation approach", *International Journal of Physical Distribution & Logistics Management*, Vol. 41 No. 8, pp. 732-749.

Lin, C.Y. and Ho, Y.H. (2008), "An empirical study on logistics service providers' intention to adopt green innovations", *Journal of Technology Management and Innovation*, Vol. 3 No. 1, pp. 17-26.

McKinnon, A., Browne, M. and Whiteing, A. (2012), *Green Logistics: Improving the Environmental Sustainability of Logistics*, Kogan Page, London.

McKinnon, A.C. (2010), "Product-level carbon auditing of supply chains (environmental imperative or wasteful distraction?)", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 Nos 1-2, pp. 42-60.

McLeod, F., Cherret, T. and Song, L. (2006), "Transport impacts of local collection/delivery points", *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management*, Vol. 9 No. 3, pp. 307-317.

Mangiaracina, R. and Perego, A. (2009), "Payment systems in the B2c e-commerce: are they a barrier for the online customer?", *Journal of Internet Banking and Commerce*, Vol. 14 No. 3, pp. 1-16.

Mangiaracina, R., Perego, A. and Campari, F. (2012), "Factors influencing B2c e-commerce diffusion", *World Academy of Science, Engineering and Technology*, Vol. 65, pp. 311-319.

Marchet, G., Melacini, M. and Perotti, S. (2014), "Environmental sustainability in logistics and freight transportation: a literature review and research agenda", *Journal of Manufacturing Technology Management*, Vol. 25 No. 6, pp. 775-811.

Matthews, H.S. and Hendrickson, C.T. (2003), "The economic and environmental implications of centralized stock keeping", *Journal of Industrial Ecology*, Vol. 6 No. 2, pp. 71-81.

Matthews, H.S., Hendrickson, C.T. and Soh, D.L. (2001), "Environmental and economic effects of e-commerce: a case study of book publishing and retail logistics", *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1763 No. 1, pp. 6-12.

Matthews, H.S., Williams, E., Tagami, T. and Hendrickson, C.T. (2002), "Energy implications of online book retailing in the United States and Japan", *Environmental Impact Assessment Review*, Vol. 22 No. 5, pp. 493-507.

Meixell, M.J. and Luoma, P. (2015), "Stakeholder pressure in sustainable supply chain management: a systematic review", *International Journal of Physical Distribution & Logistics Management*, Vol. 45 Nos 1/2, pp. 69-89.

Meixell, M.J. and Norbis, M. (2008), "A review of the transportation mode choice and carrier selection literature", *International Journal of Logistics Management*, Vol. 19 No. 2, pp. 183-211.

Mokhtarian, P.L. (2004), "A conceptual analysis of the transportation impacts of B2C e-commerce", *Transportation*, Vol. 3 No. 3, pp. 257-284.

Mollenkopf, D., Stolze, H., Tate, W. and Ueltschy, M. (2010), "Green, lean and global supply chain strategies", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 Nos 1/2, pp. 14-41.

Mouratidis, H. and Cofta, P. (2010), "Practitioner's challenges in designing trust into online systems", *Journal of Theoretical and Applied Electronic Commerce Research*, Vol. 5 No. 3, pp. 65-77.

Mulpuru, S. (2013), "The state of retailing online 2013: key metrics and initiatives", available at: www.forrester.com/The+State+Of+Retailing+Online+2013+Key+Metrics+And+Initiatives/fulltext/-/E-RES89902 (accessed October 30, 2013).

Natarajarathinam, M., Capar, I. and Narayanan, A. (2009), "Managing supply chains in times of crisis: a review of literature and insights", *International Journal of Physical Distribution & Logistics Management*, Vol. 39 No. 7, pp. 535-573.

Ngai, E.W.T. and Wat, F.K.T. (2002), "A literature review and classification of electronic commerce research", *Information & Management*, Vol. 39 No. 5, pp. 415-429.

Park, E.J., Kim, E.Y., Funches, V.M. and Foxx, W. (2012), "Apparel product attributes, web browsing, and e-impulse buying on shopping websites", *Journal of Business Research*, Vol. 65 No. 11, pp. 1583-1589.

Park, M. and Regan, A. (2004), *Issues in Home Delivery Operations*, University of California, Transportation Center, Los Angeles, CA.

Peng, L., Li, Q. and Zhang, X. (2005), "Optimism or pessimism: environmental impacts of the e-commerce", *Environmental Informatics Archives*, Vol. 3, pp. 263-269.

Perego, A., Perotti, S. and Mangiaracina, R. (2011), "ICT for logistics and freight transportation: a literature review and research agenda", *International Journal of Physical Distribution & Logistics Management*, Vol. 41 No. 5, pp. 457-483.

Pettit, S. and Beresford, A. (2009), "Critical success factors in the context of humanitarian aid supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 39 No. 6, pp. 450-468.

Plepys, A. (2002), "The grey side of ICT", *Environmental Impact Assessment Review*, Vol. 22 No. 5, pp. 509-523.

Porter, M.E. and Kramer, M.R. (2006), "Strategy and society: the link between competitive advantage and corporate social responsibility", *Harvard Business Review*, Vol. 84, pp. 78-92.

Primerano, F., Taylor, M.A.P., Pitaksringkarn, L. and Tisato, P. (2008), "Defining and understanding trip chaining behavior", *Transportation*, Vol. 35 No. 1, pp. 55-72.

Punakivi, M. and Saranen, J. (2001), "Identifying the success factors in e-grocery home delivery", *International Journal of Retail & Distribution Management*, Vol. 29 No. 4, pp. 156-163.

Punakivi, M., Yrjölä, H. and Holmström, J. (2001), "Solving the last mile issue: reception box or delivery book?", *International Journal of Physical Distribution & Logistics Management*, Vol. 31 No. 6, pp. 427-439.

Reijnders, L. and Hoogeveen, M.J. (2001), "Energy effects associated with e-commerce: a case study concerning online sales of personal computers in the Netherlands", *Journal of Environmental Management*, Vol. 62 No. 3, pp. 271-282.

Rizet, C., Cornélis, E., Browne, M. and Léonardi, J. (2010), "GHG emissions of supply chains from different retail systems in Europe", *Procedia – Social and Behavioral Sciences*, Vol. 2 No. 3, pp. 6154-6164.

Rodiguez-Ardura, I., Meseguer-Artola, A. and Vilaseca-Requena, J. (2008), "Factors influencing the evolution of electronic commerce: an empirical analysis in a developed market economy", *Journal of Theoretical and Applied Electronic Commerce Research*, Vol. 3 No. 2, pp. 18-29.

Romm, J. (2002), "The internet and the new energy economy", *Resources, Conservation and Recycling*, Vol. 36 No. 3, pp. 131-152.

Rotem-Mindali, O. (2010), "E-tail versus retail: the effects on shopping related travel empirical evidence from Israel", *Transport Policy*, Vol. 17 No. 5, pp. 312-322.

Rotem-Mindali, O. and Salomon, I. (2007), "The impacts of e-retail on the choice of shopping trips and delivery: some preliminary findings", *Transportation Research Part A*, Vol. 41 No. 2, pp. 176-189.

Shao, T. and Liu, Z. (2012), "How to maintain the sustainability of an e-commerce firm? From the perspective of social network", *International Journal of Networking and Virtual Organizations*, Vol. 11 No. 3, pp. 212-224.

Siikavirta, H., Punakivi, M., Kärkkäinen, M. and Linnanen, L. (2003), "Effects of e-commerce on greenhouse gas emission: a case study of grocery home delivery in Finland", *Journal of Industrial Ecology*, Vol. 6 No. 2, pp. 83-97.

Sivaraman, D., Pacca, S., Mueller, K. and Lin, J. (2007), "Comparative energy, environmental, and economic analysis of traditional and e-commerce DVD rental networks", *Journal of Industrial Ecology*, Vol. 11 No. 3, pp. 77-91.

Srivastava, S.K. (2007), "Green supply-chain management: a state-of-the-art literature review", *International Journal of Management Reviews*, Vol. 9 No. 1, pp. 53-80.

Sui, D.Z. and Rejeski, D.W. (2002), "Environmental impacts of the emerging digital economy: the e-for-environment e-commerce?", *Environmental Management*, Vol. 2 No. 29, pp. 155-163.

Taniguchi, E. and Kakimoto, Y. (2003), "Effects of e-commerce on urban distribution and the environment", *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 5 October, pp. 2355-2366.

Tehrani, S.M. and Karbassi, A.R. (2005), "Application of e-commerce in local home shopping and its consequences on energy consumption and air pollution reduction", *Iranian Journal of Environmental Health Science Engineering*, Vol. 2 No. 4, pp. 247-250.

Tehrani, S.M., Karbassi, A.R., Ghoddosi, J., Monavvari, S.M. and Mirbagheri, S.A. (2009), "Prediction of energy consumption and urban air pollution reduction in e-shopping adoption", *Journal of Food, Agriculture & Environment*, Vol. 7 No. 4, pp. 898-903.

Teo, J.S.E., Taniguchi, E. and Qureshi, A.G. (2012a), "Evaluating city logistics measure in e-commerce with multi-agent systems", *Procedia – Social and Behavioral Sciences*, Vol. 39, pp. 349-359.

Teo, J.S.E., Taniguchi, E. and Qureshi, A.G. (2012b), "Evaluation of distance-based and cordon-based urban freight road pricing in e-commerce environment with multi-agent model", *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2269, pp. 127-134.

Thornton, R.V. and Ferrone, R. (2001), "The environment, e-commerce, and sustainability", *Environmental Quality Management*, Vol. 10 No. 3, pp. 85-91.

Tiwari, S. and Singh, P. (2011), "E-commerce: prospect or threat for environment", *International Journal of Environmental Science and Development*, Vol. 2 No. 3, pp. 211-217.

Van Loon, P., Deketele, L., Dewaele, J., McKinnon, A. and Rutherford, C. (2014), "A comparative analysis of carbon emissions from online retailing of fast moving consumer goods", *Journal of Cleaner Production*, doi:10.1016/j.jclepro.2014.06.060, available at: http://dx.doi.org/10.1016/j.jclepro.2014.06.060

Velásquez, M., Ahmad, A.R. and Bliemel, M. (2009), "State-of-the-art in e-commerce carbon footprinting", *Journal of Internet Banking and Commerce*, Vol. 14 No. 3, pp. 1-21.

Venus, L.Y. (2011), "Green management practices and firm performance: a case of container terminal operations", *Resources, Conservation and, Recycling*, Vol. 55 No. 6, pp. 559-566.

Wang, L. and Yu, Y. (2012), "E-commerce promote the development of low-carbon economy in Jilin Province", *Information Technology Journal*, Vol. 12 No. 3, pp. 462-465.

Wang, Y. and Lalwani, C.S. (2007), "Using e-business to enable customised logistics sustainability", *International Journal of Logistics Management*, Vol. 18 No. 3, pp. 402-419.

Weber, C.L., Koomey, J.G. and Matthews, H.S. (2010), "The energy and climate change implications of different music delivery methods", *Journal of Industrial Ecology*, Vol. 14 No. 5, pp. 754-769.

Wei, Z. and Zhou, L. (2011), "Case study of online retailing fast fashion industry", *International Journal of e-Education, e-Business, e-Management and e-Learning*, Vol. 1 No. 3, pp. 195-200.

Weltevreden, J.W.J. and Rotem-Mindali, O. (2009), "Mobility effects of b2c and c2c e-commerce in the Netherlands: a quantitative assessment", *Journal of Transport Geography*, Vol. 17 No. 2, pp. 83-92.

Wiese, A., Toporowsky, W. and Zielke, S. (2012), "Transport-related CO_2 effects of online and brick-and-mortar shopping: a comparison and sensitivity analysis of clothing retailing", *Transportation Research Part D*, Vol. 17 No. 6, pp. 473-477.

Williams, E. and Tagami, T. (2003), "Energy use in sales and distribution via e-commerce and conventional retail: a case study of the Japanese book sector", *Journal of Industrial Ecology*, Vol. 6 No. 2, pp. 99-114.

Winter, M. and Knemeyer, A.M. (2013), "Exploring the integration of sustainability and supply chain management: current state and opportunities for future inquiry", *International Journal of Physical Distribution & Logistics Management*, Vol. 43 No. 1, pp. 18-38.

World Commission on Environment and Development (1987), *Our Common Future*, Oxford University Press, New York, NY.

Wygonik, E. and Goodchild, A. (2011), "Evaluating CO_2 emissions, cost, and service quality trade-offs in an urban delivery system case study", *IATTS (International Association of Traffic and Safety Sciences) Research*, Vol. 35 No. 1, pp. 7-15.

Xu, M., Allenby, B., Kim, J. and Kahhat, R. (2009), "A dynamic agent-based analysis for the environmental impacts of conventional and novel book retailing", *Environmental Science Technology*, Vol. 43 No. 8, pp. 2851-2857.

Yang, L. and Zhang, Y.Z. (2010), "Empirical study on evaluation of regional agri-food logistics capability in e-commerce environment based on factor analysis – a case study of Hebei Province", *Chinese Business Review*, Vol. 9 No. 12, pp. 38-43.

Yi, L. and Thomas, H.R. (2007), "A review of research on the environmental impact of e-business and ICT", *Environmental International*, Vol. 33 No. 6, pp. 841-848.

Zanni, A.M. and Bristow, A.L. (2010), "Emissions of CO_2 from road freight transport in London: trends and policies for long run reductions", *Energy Policy*, Vol. 38 No. 4, pp. 1774-1786.

Zhang, L. and Zhang, Y. (2013), "A comparative study of environmental impacts of two delivery systems in the business-to-customer book retail sector", *Journal of Industrial Ecology*, Vol. 17 No. 3, pp. 407-417.